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Declassified in Part - Sanitized Copy Approved for Release 2012/01/05 : CIA-RDP80T00246A015600030001-5

[illegible] CONDITIONS

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This year astronautics has passed an important historic landmark. After successful completion of a series of technical and scientific experiments on spaceships - satellites the cosmonaut Yuri Gagarin has performed the first orbital flight which marked the beginning of direct mastery of interplanetary space by man.

The surprisingly rapid development of space technology and quite definite prospects of the increase of the distance and duration of flights have unusually stimulated medical and biological investigations, have set new and interesting problems to solve.

Of special predominant importance for the biologist and physician are all aspects of investigations referring to the traditional problem of flight safety - protection of man and his potential fellow-travellers, the Earth's living organisms, from the detrimental influence of the extremal factors of space flight.

The development of this problem is naturally first of all connected with the most complete consideration of conditions and factors which can exert noticeable influence on the vital activities of the organism and present for the latter potential or actual danger.

The general list of the extremal factors known to us is rather extensive, but we cannot be sure that it is complete. It is quite possible that further studies in the physics of interplanetary space and biological experiments will reveal some additional conditions still unknown to us or such conditions the effect of which was not duly taken into account. In this connection it is worthwhile noting that the success in solving biological problems in a high degree depends on the general progress of scientific investigations of the cosmos.

All the factors of space flight which can exert influence on living organisms can be divided into three groups:

1) factors connected with the dynamics of the flight of a space vehicle (overloads, vibrations, noise of the engines, weightlessness);

2) factors characterising interplanetary space as a specific medium of habitation for living organisms (ultraviolet, infrared and visible radiations, ionizing radiation, concentration of gas and solid matter, peculiarities of the thermal regime and so on);

3) factors connected with more or less protracted life of organisms under artificial conditions of the cabin of a space vehicle (isolation, limited space, peculiarities of microclimate, of nutrition and the rhythm of life, etc.).

In solving the problem of flight safety the strategy of physiologists is rather clear and simple.

On the basis of the experience accumulated in special experiments on animals and then on man the possible physiological (biological) effects are estimated, as well permissible limits of the strength and duration of the action of this or that factor or a complex of factors. If the probability of the adverse action is revealed, then methods of increasing the resistance of the organism are found by developing its natural compensatory mechanisms or by using appropriate protective devices.

The natural desire of the physiologist to remove any discomforting influence of the flight factors is limited by the fact that he realises actual difficulties standing on the path of the technical solution of the problem.

This usually results in a reasonable compromise combining the definite requirements of the living organism and capacities of a space vehicle.

The expounding of some physiological data referring to the problem of flight safety will probably be of interest for those who design or plan the use of manned space vehicles.

Overloads

Overloads originating during the placing of a vehicle into an orbit and on the trajectory of descent can adversely effect the pilot's health and working capacities, especially in the case of the vehicle's deviation from the calculated trajectory.

It is important to find out not only maximal permissible values of overloads, but also to understand clearly what is the nature of the physiological changes involved and how to overcome them.

The resistance of the organism to overloads is much higher, if they act in perpendicular to the longitudinal axis of the body (transverse overloads). However, in this case too disorders in breathing, hemodynamics and nervous regulation at a definite instant reach a critical value. The majority of the investigators opine that the leading part can be played by disorders of gas exchange in the lungs.

In experiments carried out on dogs we had an objective to investigate the general condition of external respiration, hemodynamics of the pulmonary circulation and the degree of oxygenation of blood at transverse overloads with the value of 3, 6, and 9 units.

It was shown (A.Kiselyov and others) that at an overload of 3 units the pulse pressure in the right ventricle remains constant. At an overload of 6 units it increases, as a rule, during the rotation of the centrifuge on the average by 16 per cent and at 9 units it increases by 62 per cent, as compared with the initial level.

Of interest are results of measurements of the blood stream and the oxygen content in the arterial blood. A direct dependence of the blood oxygenation on the rate of the blood stream has been noted which testifies to the active participation of the hemodynamics of the pulmonary circulation in the oxygenation of the blood in the lungs at [illegible], despite the decrease of the aeration of the lungs due to decrease of their ventilation, the active rearrangement of the pulmonary circulation can ensure within certain limits the preservation of the necessary blood oxygenation level.

It is quite probable that the limit of compensatory possibilities in this case is determined by the character of the reaction of circulation. There are reasons to believe that there is inequality of the volumes of the blood ejected by the right and left ventricles with the predominance of the stroke volume of the right ventricle.

If the latter supposition is true, then taking into account the progressing storage of the blood in the lungs, it is difficult to imagine the possibility of the man's stay under conditions of increased gravitation for a lengthy period of time.

Failure of compensatory mechanisms leads to a critical conditions, to a sharp disturbance of the working capacities, to disorder of vital functions.

It was practically important to select such test on the basis of which it would be possible to predict beforehand the onset of the critical phase, to determine the time of the start of decompensation at any combinations of the value and duration of the action of overloads.

As one of the possible indexes we have chosen a bioelectric reaction of the cortex (EEG). Experiments were conducted on rabbits subjected on the centrifuge to the action of transverse overloads of 2-14 units.

A definite phase succession in changes of the bioelectric activities of the cortex was revealed (G. Inozimov, A. Razumeyev). The first phase appeared with the beginning of the rotation of the centrifuge and was expressed in a decrease of the biopotential voltage, in a decrease of the number of slow waves and an increases in heart and respiration rates was recorded. The second phase was characterized by an increase of the synchronization of the cortical potentials, by the appearance of slow rhythms (2-4 hz) and spindles. The heart and respiration rates remained enhanced.

The third phase was characterised by the definitely expressed synchronization of biopotentials. As a rule, it originated at overloads more than 6 units and was accompanied by a decrease in heart and respiration rates (in 30 per cent extrasystoles and arhythmia were observed).

Depending on the initial character of the bioelectric activities of the cortex when overloads act, three types of changes in biopotentials were revealed (see Fig. 1), from the picture of which it was not difficult to determine the time of the beginning of the second phase - the phase of primary decompensation.

An analysis of the material has shown that the time of the beginning of the primary decompensation phase as a function of the value of overload is expressed in the form of a rectangular hyperbola similar to the Goorweg-weiss curve (See Fig. 2).

The picture was very similar to that observed on the E. E. G. (electroencephalogram) during the action of hypoxy and ionising irradiation.

This work was further developed by the attempt to elucidate the mechanisms of the action of overloads on the central nervous system. In particular the influence of aminazine was tested as a means of blocking the impulsation at a level of the reticular formation of the middle brain. The infusion of aminazine (10 mg/kg) removed the reactions of the bioelectric activities, of breathing and the cardiovascular system to the action of overloads. Critical disorders were not developed under conditions of the experiment.

Attempts in the above indicated directions seem to open bright prospects. It is necessary and in our opinion possible to select tests-foretokens of functional disorders which can serve as an objective diagnostic criterium for the estimation of the astronaut's health condition and quite possible would be one of the command signals for the switching on of appropriate protective devices.

Always an objection can be raised that the results obtained in the laboratory experiments on the centrifuge cannot be fully applied to the solution of problems connected with actual flight.

The difference of conditions is obvious. In actual flight overloads are combined with a complex of other factors, the pilot's emotional stress is of course of the main importance among them.

A comparison of the data obtained from the tests on the centrifuge and on the active position of the actual flight provides an instructive material. From their subjective impressions Yuri Gagarin and Herman Titov unanimously estimated these tests as very similar. They believe that accompanying factors did not complicate the tolerance of overloads. On the other hand, notable is the fact that the frequency of pulse and breathing as well as other objective indexes of the condition of some physiological functions during flight considerably differed from those registered on the centrifuge (see Fig. 3). It is difficult to doublt that this was a result of the definite emotional stress.

As can be judged from the recent publication by W. Augerson and P. Laughlin, similar data were obtained during Alan Shepard's flight.

We have touched upon some problems referring to the physiology of overloads – the sphere which for a long time have attracted investigators' attention and in which defini successes have been achieved.

At the same time we cannot ignore a large number of new problems. Some of them are dictated by the logic of investigations, others are caused by practical needs of astronautics. Other branches of space physiology are less developed. As an example we can refer to the physiology of weightlessness.

Weightlessness

Weightlessness is one of the characteristic factors of space flight. There is no doubt that it can be removed by the creation. of artificial gravitation aboard a spaceship. However, whether it is absolutely necessary and what values of artificial gravity should be recommended are problems requiring further experimental solution.

It should be pointed out that our data on the physiology of weightlessness are limited, especially because all the attempts to simulate this specific state at the Earth have encountered great difficulties and have not practically been crowned with success.

Investigations on special stands with the immersion into liquid, in airplanes and partly ballistic rockets are of a considerable, but still auxiliary importance in the solution of this difficult problem. The main method is undoubtedly a direct experiment in orbital flight when the state of weightlessness can last unlimitedly long.

Many times apprehensions have arisen that sensory, somatic and vegetative disorders will limit the possibility of man's stay in conditions of weightlessness.

Biological experiments in orbital flights have caused some uncertainty. In experiments with Laika, Belka, Strelka, Mushka, Pchelka, Chernushka and Zvyezdochka it was shown that during the first period of the animals' stay under conditions of zero-gravity a definite tendency is observed to recovery of the main physiological indexes to initial levels after expressed changes originating on the active portion of flight, when the engines were working.

During the first two hours some changes in the functional condition of the heart could be revealed. They were expressed in a changed in the intensity of cardiac tones, in lengthening of the first tone duration, in an increase of time of the blood expulsion from the heart into large vessels. The above changes disappeared rather quickly, but in [illegible] cardiography data the decrease of the systolic index up to 23-26% and some charges in the wave T were recorded. During the flight of Belka and Strelka for this period a considerable increase of the dogs' frequency of pulse and respiration rate as well as an increase of arterial pressure were recorded. By the end of the diurnal orbital flight the above changes were not revealed.

The described picture is within the framework of functional changes which do not lead to noticeable circulation disturbances. However, some phenomena referring to the neuro-humoral regulation of the cardiovascular system draw one's attention and deserve special mentioning.

Already in the experiment with Laika it was shew that the time of recovery of the heart contractions to the normal in conditions of weightlessness was approximately by three times greater than with the action of the same accelerations on the Earth. In addition to this, consistent analysis of the animals' electrocardiograms has shown that during first four-six hours of orbital flight the fluctuations of the frequency of the heart beat (the difference between the maximum and minimum values of the cardic rhythm for 10 seconds in time intervals - RR) undergo considerable and ever increasing (above normal values) variations (see Table 1). Relative instability of the rhythm of the heart beat though expressed in a less degree, remained to the end of the stay under conditions of weightlessness. The depth and frequency of respiration were characterised by a noticeable nonuniformity (R. Bayevsky).

It should be pointed out that a similar, though less expressed picture of the rhythm fluctuations was observed in Yuri Gagarin's E.K.G.

All these indicate to a definite instability, lability of the central apparatus controlling vegetative functions. An impression is created of some periodic wave-like change of sympathetic and parasympathetic influences.

It can be assumed that here the sensory sphere is to be blamed, i.e. a change in the afferent impulses under conditions of weightlessness, the probability of which was predicted by many authors.

The most evident and demonstrative confirmation of this viewpoint would be disturbances of spatial analysis and the appearance of vestibular symptoms.

Something close to this was observed during tests on men in airplanes with repeated alternating action of short-time weightlessness and overloads. However, the conditions of these experiments differ from a protracted stay in conditions of complete weightlessness.

Results of astronauts' flights were naturally anticipated with great interest. A. Shepard spent five minutes under conditions of weightlessness, Y. Gagarin endured zero-gravity for more than an hour. Neither Shepard, nor Gagarin marked any disturbances in sensory and motor spheres.

Data recorded during Herman Titov's flight are being processed. However, it is known that during the whole flight the astronaut retained a sufficient level of working capacities. No pathological indices were observed in his main physiological functions.

At the same time, as a thoughtful, keen observer, Titov noted some important symptoms. In conditions of weightlessness unpleasant sensations of the vestibular character, were felt stronger and stronger especially when the astronaut sharply turned his head or was observing swiftly moving objects. After some period after sleep these phenomena decreased, but did not disappear before the beginning of the action of overloads during the ship recovery to Earth. Thus, the sensation of some discomfort accompanied the considerable portion of the flight and resembled seasickness.

H. Titov's observations have attracted great attention. They require careful analysis and undoubtedly will serve as an initial point for special investigations in this direction.

Very fruitful for such an analysis would be the conception on the interaction of afferent systems which was so successfully developed by the late Academician L. Orbeli (see L.A. Orbeli, "Problems of High Nervous Activities", published by the U.S.S.R. Academy of Sciences, 1949).

The most essential in this conception is the statement about the unity of the integral (in some sense generalized) reaction of the nervous system with simultaneous specific activity of some individual nervous apparatus.

The organism is subjected to many influences coming from the environment, from inner organs and various working apparatus. Therefore, it is necessary to take into account the constantly existing interaction of exteroceptors, interoceptors and proprioceptors.

In addition to this, the interaction inside the individual systems should be taken into account, for instance, between proprioceptors of the motor and vestibular apparatus, not speaking about the interaction existing between the labyrinth and otolith apparatus of the latter.

Thus, a complex and very dynamic picture of the interaction of numerous nervous apparatus (afferent systems) arises before us on the basis of which the functional state of the central nervous system is formed, its tonus and the organism current activities. A condition of weightlessness sets a number of receptor apparatus under unusual circumstances of functioning. The adequate gravitational stimulant decreases or completely disappears.

Undoubtedly the functional deafferentiation of this kind should leave some traces.

It is more natural to assume that here an obvious cause arises for disorder of the functional condition of the central nervous system.

The question, therefore, is now essential the consequences of such deafferentation can be for the organism, how and when they will show themselves.

The consequence of the exclusion of the otolith reception, of the partial reduction of the cutaneous reception and may be other kinds of reception is decrease of the normal volume of afferent impulses and violation of spatial analysis (orientation in space). Against this background a relative predominance of afferentation from labyrinths originates more easily, followed by a prolonged irritation which can lead to extreme reactivity, violation of coordination and to development of a seasickness syndrome.

The expounded scheme seems to be probable, but undoubtedly it needs experimental verification and more precise definition.

From the practical viewpoint it is important to stress that the nervous system, fortunately, is characterised by an expressed plasticity, and compensatory possibilities, which make it feasible to restore the lost contact with the outer world by means of substituting one functions by others.

However, we do not know how far this principle can be extended in the case of weightlessness.

The decisive word will belong to the experiment.